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Using a serious game to promote community-based awareness and prevention of neglected tropical diseases

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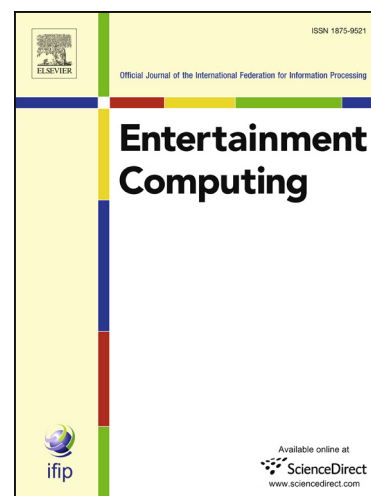
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Article title: Using a serious game to promote community-based awareness and prevention of neglected tropical diseases

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Abstract:

A serious game is presented which embodies an approach to disease prevention and management that is community-based and incorporates principles of the One Health framework---a broader view of healthcare that encompasses people, animals and the environment. The game focuses specifically on two related neglected and emerging infectious tropical diseases, namely Visceral Leishmaniasis (VL) and American Cutaneous Leishmaniasis (ACL). It seeks to inform and encourage changes in behaviours and attitudes in local populations, while involving multidisciplinary teams of healthcare professionals and researchers. The design of the learning outcomes, gameplay, client interface, and architecture of the game are discussed in detail, along with the process of collaboration among a team of computer scientists, designers, medical researchers, and practitioners which underpinned the development of the game. An expert study conducted to gather feedback from a multidisciplinary group of participants comprising medical researchers, veterinarians, healthcare service administrators, and community healthcare providers is presented which forms part of our initial assessment of this approach. The results of this study and their implications for the design of similar health-related serious games are also discussed.

## Using a serious game to promote community-based awareness and prevention of neglected tropical diseases

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### Abstract

A serious game is presented which embodies an approach to disease prevention and management that is community-based and incorporates principles of the One Health framework—a broader view of healthcare that encompasses people, animals and the environment. The game focuses specifically on two related neglected and emerging infectious tropical diseases, namely Visceral Leishmaniasis (VL) and American Cutaneous Leishmaniasis (ACL). It seeks to inform and encourage changes in behaviours and attitudes in local populations, while involving multidisciplinary teams of healthcare professionals and researchers. The design of the learning outcomes, gameplay, client interface, and architecture of the game are discussed in detail, along with the process of collaboration among a team of computer scientists, designers, medical researchers, and practitioners which underpinned the development of the game. An expert study conducted to gather feedback from a multidisciplinary group of participants comprising medical researchers, veterinarians, healthcare service administrators, and community healthcare providers is presented which forms part of our initial assessment of this approach. The results of this study and their implications for the design of

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similar health-related serious games are also discussed.

*Keywords:* Serious games for healthcare, Community healthcare, Community education, Disease prevention, Neglected tropical diseases

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## 1. Introduction

The widespread availability and use of ICT, especially mobile devices, amongst people living in remote regions, as well as their increasing connectivity to the internet, are making it possible to consider the use of technology as a potential platform for delivery of otherwise costly public healthcare services to these remote populations. The use of technology to support health promotion efforts, and provide low-cost educational services to community healthcare professionals and local population seems particularly promising. These services include community-based interventions to promote better understanding of the complex mechanisms implicated in the transmission of human and animal zoonotic diseases, as well as encouraging the adoption of preventative measures.

Prevention strategies are particularly important for “neglected diseases” [1], which affect low-income populations and could be minimized through effective educational strategies. In here, we focus on a group of diseases, namely Visceral Leishmaniasis (VL) and American Cutaneous Leishmaniasis (ACL), whose incidence rates have increased considerably in recent years in the Latin American region, particularly in Brazil [2, 3], due to factors such as urbanization, migration, deforestation, etc. [4].

These increasingly complex examples of global changes paved the way for further integration of two already recognized holistic concepts: (a) Hippocrates’ association between human health and the surrounding environment, expressed some 400 BC by his “On Airs, Waters, and Places,” and (b) Schwabe’s concept of One Medicine, which merged, in the last century, human and veterinary medicines. These concepts became integrated in the 21<sup>st</sup> century by an overall concept known as One Health. This concept came to underpin inter- and multidisciplinary efforts, conducted at local, national, and global levels, which are

aimed at addressing human, animal and environmental health issues, recognising that humans, pet animals, livestock and wildlife are inextricably connected to each other and to their social and natural environments [5].

30 The One Health framework, allowing systems theory to be applied to the complex interactions of human and animal health in their “social-ecological systems”, was chosen to serve the basis for the health education and disease prevention strategy presented here. Vector-borne zoonotic diseases, such as ACL and VL, are particularly suited to our One Health-based serious game approach, 35 because their transmission cycles involve humans, pet animals, livestock and wildlife in connection to their natural and social environments. While ACL has been historically considered a disease of loggers who, coming from non-endemic regions, entered the forests to plunder timber, VL has been related to unplanned urbanization. On the other hand, both diseases, caused by protozoa from the 40 Leishmania genus, are transmitted by sand-flies that require very specific environments for their breeding and their biting habits: they need organic matter to breed, which is normally provided by chickens, pigs and by the rubbish that may be found around dwellings; they are attracted by humans and their dogs, as well as by livestock and wildlife, who provide the iron (found in the blood- 45 repast) which is necessary for the female sand-flies to mature their offspring [4]. Those diseases are also related to environmental changes, biodiversity losses, and human migrations [6].

As part of an ongoing long-term project [6, 7], we have focused our efforts in a region of Latin America (see Figure 1), where despite the long-standing 50 endemicity of such sandfly-transmitted diseases, the (re)emergence of Bartonellosis in Peru, the hyperendemicity of ACL in Assis Brasil, and more generally the alarming geographical spread of VL in Brazil (towards this tri-national region) are all related to the local people’s lack of knowledge of the transmission cycles of these diseases and, therefore, the neglect of preventive measures to 55 combat them.

As Reidpath et al. [8] point out “*Vector borne diseases represent a rich and dynamic interplay between the vector, the host, and the pathogen; but it is*



Figure 1: Map of the tri-national region between Brazil, Peru and Bolivia.

*an interaction that occurs within a social and cultural context as much as it is one that occurs within a physical and biological context.*” They also provide an  
 60 example of how generation and management of rubbish has a social, cultural and behavioural basis related to factors such diet, housing, shopping habits, etc, and how it contributes to the spread of vector-borne diseases (e.g. by rubbish around the home providing breeding ground for mosquito vector of the dengue virus).

65 In this paper, we introduce a game called *Dr Ludens’ LSG* (Leishmaniasis Serious Game). The approach adopted in this game will provide the basis for a series of games related to health promotion that combine information delivery and simulation of disease dynamics. In this sense, the underlying implementation and general methodology described below can be regarded as a  
 70 basic platform on which a planned Dr Ludens series will be built. This first game of the series targets the local population, including community healthcare professionals, and aims to involve them in collective tasks around their local community and individual households, where they attempt to decrease vector density and protect people and dogs against the transmission of VL and ACL.  
 75 This game forms part of a strategy to break the transmission chains of both

types of Leishmaniasis in communities, through incorporation of the game into the One Health paradigm from a perspective of interactive educational tools. We describe the process of iterative design and development of this game, which has involved close collaboration between the game designers and a team of subject matter practitioners and researchers working in the field. We also present an evaluation of our high-fidelity prototype of Dr Ludens' LSG by a multidisciplinary group of expert participants, and discuss its findings and implications for the future developments of our serious game, as well as other similar games.

## 2. Serious games for healthcare

Although computer games for purely entertainment purposes have been developed since the early 1970s, starting with games such as Pong<sup>1</sup>, it is only over the past decade that computer games have been seriously considered for educational uses. This has led to the emergence of fields such as Game-Based Learning [9, 10] with its focus on the use of games as part of the learning process in education; serious games [11], which are developed for purposes other than entertainment, and focus on objectives such as learning or training within game contexts that imitate real-world scenarios; persuasive games [12] which aim to change people's attitudes and behaviours regarding their issues of interest; and gamification [13] in education (or training, e.g. [14]), which focuses on integration of game-like elements (e.g. cognitive, emotional, social [15]) into non-game educational material.

The use of computer games for learning has generally been based on the assumption that motivating and engaging features of games [16, 17] could be employed as a means of involving players in activities that lead to more effective learning. This is because this type of learning is active, situated, experiential, problem-based, and provides immediate feedback [18]. Another common assumption is that serious games can be used not only to implicitly convey educa-

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<sup>1</sup><http://www.ponggame.org>

tional information, but also to influence the player's perceived self-efficacy (i.e. the belief that desirable events can be brought about, and undesirable events avoided, by carrying out desirable behaviour [19, 20]) through explicitly making the context and characters of the game similar to those of the player (e.g. game character suffers from the same illness as the player) [21].

These assumptions have been supported, to some extent, by empirical evidence. For instance, an extensive review of literature on serious games (as well as games in general) by Connolly et al. [22] concluded that despite the diversity of research in this area, there is clear evidence on positive impacts and learning outcomes associated with playing computer games.

Healthcare has been seen as providing special opportunities for the use of serious games [23], and health has become the leading subject area for which such games (both commercial and tailor-made [24]) have been proposed and developed [22]. Computer games are seen as being innovative tools for health promotion, particularly amongst the youth [25].

A recent survey of 108 serious games for health has been conducted by Wattanasoontorn et al. [26], who categorize these games according to their: 1) primary focus (entertainment, health, teaching), 2) stage of the disease being targeted (health monitoring, detection, treatment, rehabilitation, education), and 3) targeted user/player (general population, patient, health professional). The results indicate that nearly 50% of the games surveyed focused on training of professionals (24%) and health/well-being (23%), while the remainder targeted patients suffering from specific diseases (37%) and training of general public who are not suffering from a specific disease (15%). This shows a lack of serious games for community-based healthcare which aim to educate public about issues such as disease prevention in general, or in relation to a specific range of diseases (e.g. vector-borne diseases).

An even more recent meta-analysis of 52 serious games for healthy lifestyle promotion [27] focused on four categories of health behaviour: 1) diet and physical activity, 2) health responsibility and maintenance, 3) social behaviour, and 4) and mental health. The analysis showed that serious games increased healthy



lifestyle adoption, and improved antecedents that determine adoption across  
135 several of the health domains included in the analysis. While the overall ef-  
fect sizes were small, they were commensurable with other computer-delivered  
interventions. The effects were largest on knowledge acquisition, which corrobo-  
rates other findings on knowledge gain [28], and the observation that knowledge  
is easier to influence than outcome in computer-delivered interventions [29].  
140 However, DeSmet et al. hypothesize that serious games, due to their higher  
interactivity, visual attractiveness, and motivating fun aspect, may prove to be  
a better medium than other computer-delivered interventions in reaching their  
target audiences in large-scale deployments

[27]. These findings generally support our approach, which focuses on be-  
145 haviour change through imparting of knowledge.

Another literature review of computer games for health has been reported  
by Papastergiou [30]. This review has, however, mainly focused on the potential  
of games as part of health education (HE) and physical education (PE) for chil-  
dren and youth. The review categorizes 34 research publications into three HE  
150 (disease-related, nutrition, first-aid) and four PE (sporting injury, motor skills,  
fitness, educator's knowledge of games) areas. The results of this review show  
that although the empirical support for the effectiveness of computer games in  
HE and PE is limited, overall the findings are positive. In particular, computer  
games seem to be effective in *"promoting knowledge acquisition, development*  
155 *of positive attitudes and positive behavioural changes within the framework of*  
*HE programs addressing disease awareness, prevention and management, and*  
*targeted at children, adolescents and young adults"* [30]. More importantly, Pa-  
pastergiou concludes that *"educational effectiveness and motivational appeal of*  
*an electronic game designed for HE and targeted at young people largely depend*  
160 *on the design, development and evaluation approach followed during the creation*  
*of the game."*, and suggests that: 1) the design of the game should originate  
from the target users, 2) the design should have an emphasis on challenge and  
competition, and 3) the game interface, gameplay, and instructional aspects  
should go through *"continuous formative evaluation. . . by experts and members*

165 *of the intended target audience, and its results should inform the design and development of the game*". Following these recommendations, however, can often be challenging. For instance, involvement of potential users in developing game concepts may require special attention [31].

170 Finally, in terms of the serious games specially dealing with vector-borne diseases, Diego and Hounsell [32] provide a recent review of existing games about dengue. However, they also point out that many of these games either have limited or non-existent content, or their gameplay and content are not directly linked. Furthermore, we note that most of the reviewed games (e.g. [33, 34]) only target educational school environments, rather than the general public, and comparisons are often made between the effectiveness of serious games and other conventional in-class alternatives such as teaching material and lectures, as opposed to when other alternatives are not provided at all (e.g. to populations living in remote regions). Diego and Hounsell also present a user study comparing collaborative and individual user versions of their own game, 175 called Sherlock Dengue<sup>2</sup>. The study which was conducted with children and teenagers (aged 8-15) showed high acceptance rates by the target audience for both versions, with the collaborative version being slightly better at motivating the users, as well as being more likely to be suggested to others by the users [32].

185 As for other common vector-borne diseases such as malaria, surprisingly there are not many reported studies of the use of serious games to target them. Hartjes and Baumann [35] evaluated a web-based game designed to reduce the risk of malaria for study-abroad college students. The game allows students to experiment with different choices and follow the consequence of their decisions 190 which would result in their game character remaining healthy, becoming disabled, or dying. The study showed significant increase in post-game knowledge of malaria and players' risk perception. Another study, though very limited, was conducted by Lennon [36], which used a post-game oral debriefing method (simi-

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<sup>2</sup><http://www2.joinville.udesc.br/~larva/dengue/>

lar to an interview with open-ended questions) with one student to get feedback  
195 and comments on two different malaria-related games. Lennon suggests that  
debriefing, either oral or written (similar to a form-based questionnaire with  
open-ended questions), is an invaluable component of game design process. De-  
briefing has also been used by Lennon and his colleagues for other serious games  
targeting dengue [37], and immunity [38].

### 200 3. A serious game for Leishmaniasis

The idea of developing a serious game to combat the spread of neglected  
tropical diseases such as Leishmaniasis was the result of our involvement with  
various One Health activities related to Leishmaniasis surveillance in the tri-  
national region of Amazonia (see Figure 1). These activities have included:  
205 identification of the main factors affecting the hyperendemicity of ACL in Acre-  
Brazil; use of qualitative field-based ethnographic work to validate transmission  
factors in Acre-Brazil; ongoing research on the regional migration patterns and  
public policies related to the (re)emergence of Leishmaniasis; ongoing research  
aimed at developing an Early Warning System for Leishmaniasis and Bartonel-  
210 losis in the tri-national region; and the development of a tele-health system for  
mobile devices to allow collection and sharing of epidemiological surveillance  
data [6, 7], spatio-temporal visualization of disease case data [39], and remote  
diagnostic support for Leishmaniasis and Bartonellosis [40].

Through these activities during more than a decade, our research team has  
215 gained extensive knowledge, not only of the issues related to healthcare matters  
pertaining to Leishmaniasis, but also of those concerning the local population,  
their lifestyle, living and work environments, education, etc. For instance, we  
have observed that computers are widely available in the tri-national region,  
even among the lower-income individuals. Even in those areas where internet  
220 connectivity is poor, many people, including the youth, go to internet-cafes  
to interact with others and play online games. People also often gather in  
few locations with Wi-Fi connectivity to use their mobile devices or laptop

computers.

Therefore, the decision to utilize a serious game as a learning tool to provide the local community with information about Leishmaniasis is based on the availability of computer technology, both mobile and desktop, and internet connectivity, as well as the popularity of computer games amongst the people living in our target region. Based on experience reported in the above reviewed literature (see Section2), and on our knowledge of the local culture, we adopted the working assumptions that that when Dr Ludens' LSG is made available, people are likely to play the game, learn from the information embedded in it, and subsequently change their behaviour by taking actions to prevent the spread of Leishmaniasis. These assumptions remain to be fully confirmed through a broader study of the intervention as a whole, as discussed later in this paper (see Section 9.)

We also wish to involve medical practitioners and researchers dealing with VL and ACL, by providing them with a scientifically accurate disease simulation model. This is an important potential use of serious games, as highlighted by a global health report, *"hybridizing such games with robust simulation could help health workers and scientists visualize how diseases and interventions might play out"* [41]. Therefore we took the prospective involvement of these professionals into account when designing the game simulation back-end (see Section 6). In this paper, however, we focus mainly on the use of Dr Ludens' LSG as a vehicle for health promotion, and ultimately disease control, through dissemination of knowledge among the local population, including community-based healthcare professionals who are generally responsible for day-to-day primary care within the communities but often have no degree tertiary education [42, 6].

Finally, it should be pointed out that the idea of employing a serious game is an unconventional approach to controlling neglected tropical diseases by involving general population (see Section2), considering the fact that, for instance, the existing efforts to control VL and ACL transmission have, since the identification of the antimonials for treatment, relied mainly on pharmaceutical and biomedical developments. The development of vaccines (for dogs, so far), and

chemicals to either break disease transmission (by treating of humans and, in  
255 some countries, dogs) or prevent human and animal infection through use of  
insect repellents, have helped slow the spread of the disease but have failed so  
far in halting it or stabilising its pace. However, due to the lack of serious ef-  
forts, the World Health Organization has listed all types of Leishmaniasis as  
neglected tropical diseases, and recognizes that they are considered “*diseases of*  
260 *the poor*”, and therefore lack investments from the pharmaceutical and biomed-  
ical industries.

#### 4. Designing the learning outcomes

As dit Dariel et al. [43] point out, one of the main differences between  
serious games and other games is that the former are designed to provide specific  
265 learning outcomes, supported by established educational models and learning  
theories, which determine the nature of the learning environment, and guide the  
sequencing and embedding of the required learning instructions into the game  
to assist the player in meeting those specific outcomes [44].

Various educational models have been proposed and used to specify learn-  
270 ing outcomes of serious games [22]. One commonly used model for designing  
instructional elements of such games is constructivism, which “*describes educa-  
tion gained from reflecting on our experiences and constructing our own under-  
standing of the world we live in*” [45]. The design of the learning outcomes of  
Dr Ludens’ LSG is inspired by this type of constructivist model.

275 It is also important to note that one must distinguish between skills-based  
learning outcomes, cognitive outcomes, and affective outcomes (e.g. beliefs,  
attitudes) [46]. The affective outcomes are particularly important in design of  
serious games because they relate to the potential of games to not only help  
players to learn, but also to change their emotions and attitudes [22]. These  
280 learning outcomes (skill-based, cognitive, and affective) need to be organized  
into various levels, progress through which depends on the player achieving the  
learning skills and competencies of the outcomes embedded into each level [44].

Boyle et al. [18] point out that although changing behaviour is perhaps the most difficult task in terms of the expected outcomes, various theoretical models of attitude and behaviour change, and persuasion have been proposed, which could  
285 be used to guide the design of serious games.

Boyle et al. [18] also point out that *“developing and evaluating games for specific purposes whether learning or behaviour change is a very complicated enterprise requiring an understanding of the design of games, knowledge of the relevant content or subject area, knowledge of motivation, pedagogy and behaviour  
290 change, an understanding of how to select a game which will address the required learning or behavioural outcomes and evaluation techniques”*. We have, therefore, designed and developed our serious game through a user-centred design process, involving close collaboration between our team of game designers and  
295 a multidisciplinary group of researchers which includes medical doctors, veterinarians, entomologists, epidemiological surveillance professionals, public health professionals, and social scientists.

Furthermore, we decided to use a simulation-based environment for our serious game, as this is the most frequently occurring genre and its use in education  
300 is well-established [22]. This will also allow us to develop epidemiological models for Leishmaniasis, which could then be used to study disease spread, interventions methods, etc. [47]. The use of such models has been recommended for better understanding and controlling other vector-borne diseases such as malaria, as powerful tools that allow integrating information from different disciplines  
305 [48].

Finally, we made our game a multi-player one due to the potential of such serious games designed for health education [30]. As mentioned earlier, collaborative games are also more effective in motivating the players, and are more likely to be suggested to others [32].

## 310 5. Game concept for Dr Ludens' LSG

Dr Ludens' LSG has been designed to accommodate the need for targeting users coming from a diverse local population, with varying levels of access to ICT and internet connectivity, as well as community healthcare professionals. As such, Dr Ludens' LSG can be played on a range of mobile devices and  
315 computers, with synchronous or asynchronous connection to the game server.

A simulation of a geographical region, spanning urban and rural settings, underpins the gameplay. Features of the local geography that are relevant to the spread of ACL and VL, and are immediately recognizable by the players (e.g. location of bodies of water, vegetation, forests, distribution of animals  
320 and possible foci of sandflies, etc.) are included in the simulation. Although the simulation is global, the individual players will be able to interact with small "local" regions that correspond to, say, their houses, rural properties, communal areas in their neighbourhoods, etc. The main purpose of such interactions is to enable the player to manage and tend to these areas (as in the  
325 popular social network games like FarmVille<sup>3</sup>) so as to keep potential infection of their animals, family members, neighbours or themselves in check. The tools and resources necessary in order to manage these individual areas are acquired through participation in certain in-game tasks and quizzes.

The game concept therefore involves players choosing from an urban or a  
330 rural visual game setting in which they are placed, where they are asked to interact with the in-game expert medical doctor, called Dr Ludens. The doctor then initiates a series of discussions with the players, in a manner similar to role-playing games, during which they learn about the tasks they need to perform, as well as the reasons for performing such tasks in real-life. These include:  
335 identifying the type of sandfly that carries Leishmaniases, identifying the main breeding grounds for these sandflies, and removing rubbish and other organic matter such as leaves, branches and dirt water from around their houses and

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<sup>3</sup><http://zynga.com/games/farmville>

communal places. It is by performing these tasks that the players collect in-game points, and gradually advance to higher levels in the game.

340 As the game level advances, Dr Ludens asks the players to perform tasks with increasing levels of complexity, and as such, they learn more about Leishmaniasis and how to take preventative measures against these diseases. These tasks with varying levels of complexity include: using insect repellent lotions, acquiring insect repellent collars for dogs, acquiring and installing appropriate  
345 nets on doors and windows to reduce the number of sandflies inside the houses, acquiring, installing and using bed-nets every night, constructing holding pens at a safe distance from the houses for domestic animals that otherwise live freely around the houses—these act as buffers against the approximation of the sandflies from the surrounding forests or bushes.

350 Many of the tasks that Dr Ludens' LSG requires the players to perform have a collective element to them. These tasks encourage the players to cooperate with others to reduce the spread of Leishmaniasis in the urban or rural environment in which they live. This is to simulate the real-world settings where the spread of diseases such as VL and ACL are dependant on actions taken  
355 by the whole community. As mentioned earlier, these collaborative aspects of the game are also likely to increase its effectiveness, and encourage players to recommend the game to others, thereby making it more widely adopted.

The more complex tasks may be performed individually to collect points, but will gain extra points if the player engages others to work with them, fostering  
360 cooperation. On the other hand, if the player fails to demonstrate that, for instance, the nets are being used appropriately, or the animals are being kept in an enclosure away from the house, they will lose some of their game points; thus risking to return to a lower level of the game.

365 Finally, Dr Ludens' LSG also aims to engage medical practitioners and local community healthcare professionals. Therefore, Dr Ludens will provide scientific disease-related information to these specific players (and perhaps even more advanced players from local citizens), and facilitate discussions on various One Health topics related to the prevention of Leishmaniasis. These include schemes



for vaccination and treatment of people; vaccination and treatment of dogs; and  
 370 even the highly sensitive issue of euthanasia for dogs with Leishmaniasis.

## 6. Architecture of Dr Ludens' LSG

Figure 2 gives an overview of the three main components of the software  
 architecture of Dr Ludens' LSG. These components are:

- **Badagua:** The simulator back-end which utilizes a sophisticated simulation  
 375 model to provide realistic simulation for the effects of human, animal and  
 epidemiological activities within the entire geographical region of the game  
 environment.
- **DrLudensLSG:** The individual GUI-based game clients which are used by  
 the players to interact with the game using a range of devices. Each client  
 380 represents a sub-region of the geographical game environment.
- **DrLudensGatekeeper:** The individual gatekeepers which coordinate play-  
 ers' access to their own sub-region (*household*), record their interactions with  
 the game (e.g. their scores, etc), and mediate the communication between  
 the simulator and game clients.

385 The Badagua simulator provides a discrete multi-agent simulation model,  
 written in Java using the Mason library [49]. The simulator represents the map

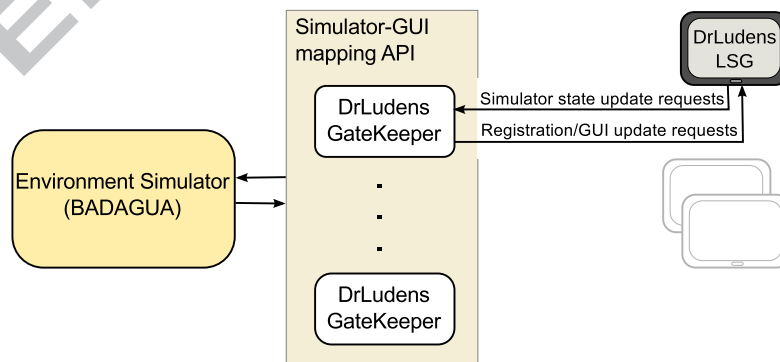


Figure 2: Architecture of Dr Ludens' LSG.

of the entire geographical game region as a sparse 2D grid. This grid is divided into sub-regions, each of which is assigned to an individual player. These sub-regions are permeable so that, given that the simulation is global, the state of one sub-region can potentially affect the state of all other regions. For example, if a player does not clear organic matter collected in their sub-region (household), this can lead to sandfly infestation, which in turn can cause the other nearby sub-regions to become infested. As mentioned previously, Dr Ludens' LSG aims to raise awareness of the collective nature of taking preventative actions to combat the spread of Leishmaniasis.

Our current multi-agent simulator populates its map with various agents that simulate the dynamics of (1) accumulation of water and organic matters, (2) reproduction, movements, and infection state of sandflies, and (3) movements and infection state of domestic animals . All the agents are parametrized, to allow the disease and sandfly cycles to be modelled according to actual scientific knowledge and data. Simulation of the dynamics of disease spread is based on a simplified SEIR (Susceptible, Exposed, Infectious, Recovered) [50].

The communication between Badagua and DrLudensLSG is based on the following protocol:

- At the start of a game session (play) DrLudensLSG connects to DrLudensGatekeeper, identifies the player and retrieves the status of the player's household (number and location of leaves, animals, water puddles, sandflies, etc). These data are mapped onto the DrLudensLSG client GUI, and unique identifiers for each object are stored on a status table maintained by DrLudensLSG.
- DrLudensLSG polls DrLudensGatekeeper (at regular intervals, depending on internet connectivity) for status updates on Badagua (animals move and become infected, sandflies reproduce, humans get infected, etc). Status updates are sent by Badagua as vectors of the form:

$$S = ([obj_1, x_1, y_1], \dots, [obj_n, x_n, y_n])$$

For each object tuple received, DrLudensLSG applies a function  $render(obj_i)$  to display the corresponding GUI element. A simple implementation of such rendering mechanism might, for instance, either ignore or map the simulation coordinates  $(x_i, y_i)$  of the object, depending on the rendering device, zoom level, selected view etc.

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- DrLudensLSG merges-in the updates and submits (1) player initiated changes (e.g. leaves cleared, puddles dried, etc), and (2) the results of the quizzes completed by the player to DrLudensGatekeeper which then requests updates to Badagua simulation, updates the database of quiz scores, etc. Requests for player-generated changes to the simulation must contain the unique identifier of objects being updated and the update operation to be performed, so that Badagua can update the simulation. Such requests are issued by DrLudensLSG to Badagua through vectors of the form:

$$U = ([obj_1, opr_1], \dots, [obj_n, opr_n])$$

where  $obj_i$  is the unique id passed on to DrLudensLSG by a preceding update from Badagua and  $opr_i$  is an operation for the simulator (e.g. `remove`, `vaccinate`, etc).

- DrLudensGatekeeper also acts as a quiz-server, in which case it exchanges messages directly with DrLudensLSG in the form of questions:

$$Q = (qid, q, [a_1, \dots, a_n])$$

where  $q$  is a question text and  $a_i$  are multiple choices.

Once the player has completed a quiz, DrLudensLSG communicates player's answer to DrLudensGatekeeper in the form of answer:

$$A = (qid, a)$$

420

where  $qid$  is the question identifier and  $a$  is the player's answer.

## 7. Game Client of Dr Ludens' LSG

As with the design of the learning outcomes of Dr Ludens' LSG, and its game concept and mechanics, the iterative design of our client has been the result of collaboration between our game designers and a multidisciplinary team  
425 of subject experts.

During this process we used a series of simple visual sketches to facilitate the initial discussions between our teams. Figure 3 shows one of the sketches used for these discussions, depicting the fictional map of the entire geographical world of Dr Ludens' LSG, including all of its individual in-game households. Figure 4,  
430 on the other hand, shows a sketch of one such household in the form of a village farm with a hut, animals, and people. We developed the visual design of a typical village farm in Amazonia in consultation with our local experts. For this, we used free vector graphics stock<sup>4</sup>, which we adopted and modified as required. Figure 5 shows one of the intermediate designs which was refined  
435 further.



Figure 3: A sketch of the geographical map of Dr Ludens' LSG.

Once we had developed the visual design of the main elements of the game client, we coded its interactive components. To make the game widely available,

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<sup>4</sup>Available at: <http://all-free-download.com/>



Figure 4: Initial sketch of a village farm used for discussions.



Figure 5: An intermediate design of a village farm.

our local experts requested that the game client should be available on mobile devices, as well as standard PCs, both as a native application and through web browsers. We chose Processing<sup>5</sup> for coding our game client prototype, as it supports the development of standard Java, JavaScript, and Android-based<sup>6</sup> interactive visual applications.

Figure 6 shows the interface of the current implementation of the game client for Android-based mobile devices. The native PC application and web

<sup>5</sup><http://www.processing.org/>

<sup>6</sup><http://developer.android.com/>



Figure 6: Interface of the game client of Dr Ludens' LSG running on: a) Samsung™Galaxy Tab 2 10.1, and b) Google™Nexus 7.

445 browser-based clients have exactly the same visual look as those shown here. The central part of the client interface shows a village farm setting, with a hut and various animals, some of which are kept under the hut. The interface includes various game tools at the top left-hand, as shown in Figure 7a. These can be selected to allow the player to perform various in-game actions such as removing infected stray dogs (Figure 8a), cleaning leaves (Figure 8b) and  
 450 as draining water puddles (Figure 8c) which all act as reservoirs and breeding grounds for sandflies. Performing these actions change the game score and statistics shown on the top right-hand side of the interface (see Figure 7b).

In addition, Dr Ludens' LSG uses quizzes to encourage learning information  
 455 more explicitly about different types of Leishmaniasis, their life-cycles, methods



Figure 7: Various game elements: a) tools (leaves, puddle, dogs, quiz, restart) and b) their associated scores.



Figure 8: The player can: a) remove infected stray dogs, b) clean leaves, and c) dry water puddles, to reduce the number of sandflies.

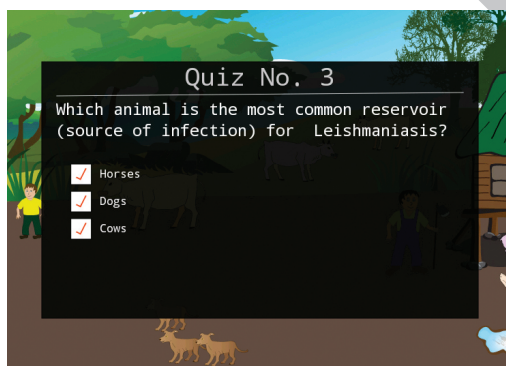


Figure 9: An example of a quiz presented to the player.

of spread, methods of control, prevention, etc. These quizzes are presented to players as shown in Figure 9. Answering quizzes correctly allows the player to collect extra points which can then be used in the game, for instance to buy bed-nets which are needed for higher level activities requested by Dr Ludens.

## 460 8. Expert evaluation

In order to assess the potential of Dr Ludens' LSG as a serious game for educating local community citizens and healthcare professionals about Leishmaniasis, we conducted a formative evaluation of the high-fidelity prototype described above with a multidisciplinary group of 20 Brazilian health professionals, covering a range of expertises encompassed by the One Health frame-  
465

work. However, despite our research links with the One Health framework, the participants of our study were not involved in the design and development of Dr Ludens' LSG.

This evaluation complemented an earlier interview-based (similar to oral-  
470 debriefing [36, 38]) pilot study we had conducted with 6 medical researchers at a conference on Leishmaniasis, to find out if Dr Ludens' LSG provided correct training and sufficient practical knowledge related to Leishmaniasis. This pilot study had highlighted various positive aspects of Dr Ludens' LSG, as well as identifying several areas for improvements in terms of its design.

475 In this section we focus on a subsequent formative evaluation, and describe its design, findings, and implications.

### 8.1. Methodology

The study took the form of a qualitative survey supported by a session where the participants were able to interact with the prototype and play a simplified  
480 game. The survey was set up as a web-based questionnaire, preceded by a desktop-based version of Dr Ludens' LSG, implemented as a Java applet for web compatibility. The study sessions started with an overview of the game, followed by a simple tutorial explaining various game elements (e.g. tools, scores) and mechanics. The participants were then given some time to play the game, after  
485 which they proceeded to answer the survey questions.

One of the authors (Dr Raquel Rangel Cesario) initially contacted the potential participants and coordinated the study session in person. However, participation in the survey was voluntary, and the respondents were able to skip any of the survey questions if they so wished. Ethics permission for the study was  
490 sought and obtained from the Ethics Committee of a participating institution.

### 8.2. Study survey

The qualitative survey consisted of 19 questions, which were divided into the following three general categories:



- 495 1. **Healthcare value**, assessment of the perceived educational value of the game to local communities (both citizens and healthcare professionals) in terms of:
- (a) raising awareness of the transmission cycle and mechanisms of Leishmaniasis, and
  - (b) fostering adoption of preventative measures.
- 500 2. **User group value**, assessment of the perceived educational value of the game to local communities, specifically to:
- (a) citizens, and
  - (b) healthcare professionals (also referred to as Community Healthcare Professionals, or CHPs).
- 505 3. **Design trade offs**, assessment of whether the *fun* or the *accuracy* elements should take priority in the implementation of mechanisms to:
- (a) provide citizens with information about preventative measures,
  - (b) provide CHPs with information about preventative measures,
  - (c) provide citizens with information about epidemiology,
  - 510 (d) provide CHPs with information about epidemiology,
  - (e) provide citizens with general medical information, and
  - (f) provide CHPs with general medical information.

Each question consisted of a rating on a 7-point Likert scale, ranging from “Strongly disagree” to “Strongly agree” for questions in categories 1 and 2, and 515 from “Fun” to “Accuracy” for those in category 3.

Questions in categories 1 and 2 also each included a free-form comments section. Although entering comments for each question was optional, nearly all (93.75%) of the responses to questions included comments, suggesting a high level of engagement in the survey by almost all participants. The survey 520 was conducted in Portuguese, and the collected comments were translated into English by one of the authors for further analysis.

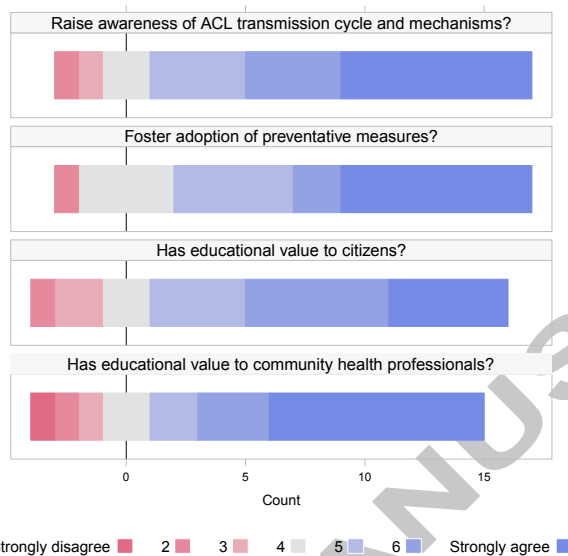


Figure 10: Ratings given to Dr Ludens' LSG with respect to perceived healthcare value (top two rows), and user group value (bottom two rows).

### 8.3. Study participants

The group of participants who took part in this study included medical researchers (5), nurses (3), other healthcare professionals (4), veterinarians (6), and healthcare administrators (2). One of the participants was in his twenties, nine were aged between 31 and 40, four were 41–50, five were 51–60, and two were over 60 years old. Thirteen of the participants were female and seven were male.

### 8.4. Results

Figure 10 (top two rows) shows the ratings given by the study participants to the perceived healthcare value of the game in terms of raising awareness of Leishmaniasis transmission cycle and mechanisms (1.a), and fostering adoption of preventative measures by the local communities (1.b). The average ratings given in both cases were very high (median values of 6 for 1.a, and 5.5 for 1.b).

535 As regards Question 1.a, positive comments highlighted the attractiveness  
and ease-of-use of the game, and the memorability of the information presented  
in a game setting as invaluable assets in educating the population, specially chil-  
dren and young people, and in supporting more formal educational measures  
initiated by teachers (*“the game will help initiate a dialogue between teachers  
540 and students”*). Negative comments, on the other hand, focused on the in-  
completeness of the information (*“this [ACL] is a complex disease, and more  
information is needed [in order for the player] to understand the disease”*), on  
information presentation issues (*“I think [the game did not make clear] that the  
phlebotomine sandflies transmit the disease”*) and on the aesthetics of the de-  
545 sign. Respondents also cautioned that the game has to be meaningful to the  
local communities in order for it to accomplish its health education goals, and  
that the involvement of healthcare educators is also very important.

Comments on Question 1.b were similar, sometimes elaborating further on  
points made in earlier comments, and highlighting that the habits of each player  
550 should be taken into account somehow when imparting information regarding  
preventative measures. Furthermore, it was noted that individual habits should  
be used to adapt the information given by the game in terms of civic participa-  
tion, environmental protection and interactions with pets, in addition to more  
immediate measures. One the participants also remarked that *“by itself, no  
555 single tool or game can accomplish success in prevention”*; that is, the game  
should be integrated into a broader context of educational programmes and  
public health campaigns through a number of media.

Figure 10 (bottom two rows) shows the ratings given by the study partic-  
ipants to the perceived educational value of the game to local communities,  
560 specifically to citizens (2.a) and healthcare professionals (2.b). The average rat-  
ings given for both questions were high, with a slight advantage for healthcare  
professionals (mean 5.53, versus 5.35 for citizens).

As regards value to citizens, respondents emphasized the role of the game  
as an educational tool (*“specially for the low-literacy population”*) but also as a  
565 way of promoting civic engagement (*“it may help people realise the importance*

of preservation and care of public spaces by the community”) and behavioural change (“the game might help change the cultural behaviour [sic] of the population”). With respect to value to healthcare professionals, participants mentioned possible use of the games by CHPs as an aid in explaining the nature of the disease, and prevention measures to local citizens. They also remarked on the possible use of Dr Ludens LSG as a communication tool (“[CHPs] would have the ability to provide more information to the population”). Several comments mentioned the use of the game as a tool for continuing professional development of the CHP (“in addition to being instructive to the [CHP], the game will help them communicate information to others”). Some respondents also alerted to contextual factors (lack of time, compatibility with professional interests, etc) which might pose risks to the adoption of a serious-game approach such as Dr Ludens’ LSG.

Figure 11 summarizes responses regarding the necessary balance between the entertainment (i.e. fun) elements of the game and the accuracy of healthcare-related information it conveyed. In general, the survey participants felt that accuracy of factual information presented by the game would be more important to healthcare professionals than to local citizens (overall means 5.7 and 4.1, respectively; higher values indicate a preference for accuracy over fun).

The balance in favour of information accuracy for healthcare professionals as compared to citizens is most pronounced in terms of epidemiology (mean 5.8 vs. 4.1; median 7 vs. 4) and preventive information (mean 5.5 vs. 4; median 6.5 vs. 4). Respondents felt that these aspects of the game could have a stronger ludic element when directed to the general public as a means of retaining their attention. It was, however, felt that excessive emphasis on educational content might also alienate some users (“the game should avoid sounding too didactic, as this might weaken the interest of potential users”). This suggests that the game should be adaptive, in that the type of information it provides, and its levels should be tailored according to specific a user group’s profile.

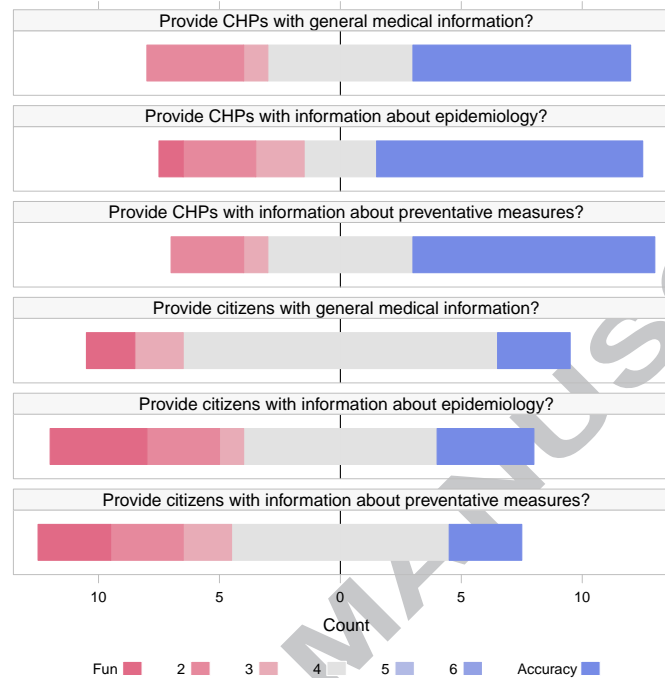


Figure 11: Comparative importance of *fun* and *accuracy* elements in different functions of the game.

## 595 9. Discussion

As mentioned in Section 2, various reviews of the literature on serious games for healthcare, as well as those for other fields, have demonstrated the difficulty of establishing the benefits of educational games in training people and in changing attitudes and behaviours. Furthermore, as discussed in Section 4, researchers have also highlighted the complexity of designing games for the purpose of learning or behaviour change [18], recommending that designers involve experts from various relevant fields in the process of game design, and pointing out the need for iterative evaluation of the instructional elements, gameplay, and interface components of serious games [30].

605 Our own experience of the process of design, development, and evaluation

of Dr Ludens' LSG, as described in this paper, has corroborated these recommendations. This is illustrated by the fact that the current evaluation of our prototype has still identified a range of issues that need to be addressed before it can be released to local populations, even though a) the initial idea behind our  
610 game originated from experts dealing for many years with our targeted diseases (i.e. VL and ACL) in the region of our interest, b) our design team involved a range of experts from different disciplines concerned with VL and ACL, c) our team of experts had intimate knowledge of the local population (both citizens and healthcare professional), and d) we have followed iterative user-centred  
615 design and development processes.

The need to balance fun and educational elements was acutely felt, and referred to in several written comments, even in comments to those questions where the trade-off between accuracy and fun was not at issue. The general perception, which also transpired in the pilot interviews (see Section 8), was  
620 that one should avoid turning the game into an entirely didactic tool, so as not to reduce its attractiveness to the general public. Young people and children are featured highly as a target user community, as many respondents felt that a serious game such as Dr Ludens' LSG has the potential to raise awareness of broader ecological issues implicated in the spread of infectious tropical diseases  
625 such as ACL and VL, and to bring about cultural changes regarding the environment and health (human and animal) which are seen by the study participants as vital for the prevention and management of these diseases.

Another point worth noting is the sharp polarization of the ratings for fun and accuracy in relation to specific user groups. In our study, fun elements  
630 were rated as highly important as regards educating the general public (for the reasons noted above), whereas accuracy was strongly preferred for CHPs. This has implications for possible development paths for the game. One alternative would be to develop distinct and separate games, targeting the two different user groups. The game aimed at the general population would focus on the ludic  
635 element as driver for cultural change towards protection of the environment, care of domestic animals etc, with a view of promoting long-term policies. On

the other hand, the game aimed at CHPs would pursue short-term benefits, focusing on educational elements and communicating more technical content.

A different alternative would be to keep a common game structure, but  
640 tailor game elements, mechanics and play to the distinct groups of players. This  
would have the advantage of allowing us to retain the underlying game simulator  
while adapting content delivery. As a further step, such content adaptation  
strategy could descend to the level of personalization, where the profiles of  
645 individual players (e.g. a structured representation of their level of knowledge,  
professional background, place of residence, etc) could be used to drive the  
presentation of content. A variant on this alternative could include a layer  
direct of communication between CHPs and the general public, thus further  
promoting social participation and education.

Finally, an important issue for future work is how the game should be rolled  
650 out and evaluated. It has been pointed out that studies involving serious games  
for health often fail to assess objective outcomes that have clinical relevance [24].  
This is likely to also prove a challenge for Dr Ludens' LSG. Unlike games that  
specifically aim to improve the health of patients (i.e. clinical interventions), Dr  
Ludens' LSG is supposed to be a public health intervention, and as such, will be  
655 inherently more complex and context dependent than serious games designed  
as clinical interventions. It is acknowledged, for instance, that randomized controlled  
trials (the widely accepted standard for evaluation of clinical interventions)  
may have to be carefully designed so as to be able to "*accommodate the  
complexity and flexibility that characterises [public health interventions]*" [51].

660 In terms of evaluating Dr Ludens' LSG as a public health intervention, the  
complexity of evaluation is illustrated by a range of pertinent questions: Would  
the local people in Assis Brasil, both lay citizens and epidemiological surveil-  
lance personnel, use such a computer game? If so, would its use change the  
behaviours of the game users in relation to the living conditions related to the  
665 regional ACL's hyper-endemicity? If so, would their behavioural change even-  
tually empower non-game-users in the same community? At what levels would  
this empowerment occur (individual, community or political?) How to field test

the effectiveness of Dr Ludens' LSG in decreasing vector density and protect local people against Leishmaniasis transmission? Could such a game be adapted  
670 to other vector-borne diseases, such as malaria, dengue and chikungunya fever, and to other tropical localities?

Given the broad spectrum of objectives that characterize the One Health approach after which we have modelled Dr Ludens LSG, an objective evaluation strategy will probably require a combination of randomized controlled trials  
675 and qualitative tools. We are currently considering the use of pre- and post-intervention KAP (knowledge, attitudes and practices) surveys [52, 53, 54] to help monitor the efficacy of our serious game strategy. KAP surveys can help identify what is currently known, believed and done by the local population with respect to Leishmaniasis and, longitudinally, determine those changed following  
680 wide scale deployment of Dr Ludens LSG.

## 10. Implications

As our review of related literature has shown, despite the promise that the use of serious games shows as a tool for educating players and changing their attitudes and behaviour, the fact remains that outside schools and other dedicated educational settings not many serious games have been developed to  
685 target neglected tropical diseases. This is perhaps because neglected tropical diseases, like different types of Leishmaniasis, are very complex to analyse and understand—as these diseases involve interactions between several human, animal, and environmental variables. Furthermore, combating NTDs goes beyond  
690 just dealing with biological disease factors, and requires addressing societal, cultural, political, economic, and other factors. There are therefore a number of issues that must be carefully considered and tackled when designing serious games to be used in such a complex context.

The first issue is related to the range of expertise required in dealing with  
695 neglected tropical diseases. This means that the design and evaluation of serious games for NTDs, and to a certain extent their development, must be carried out



in consultation with, and through direct involvement of relevant experts from medical, veterinary, environmental, and social sciences.

These experts must also be involved in identifying the type of information  
700 that needs to be included in the envisaged game. This would address the second major issue in designing serious games for NTDs, namely providing the right content. Many serious games, and indeed other game-based learning tools fail to convey learning content [55] by focusing mainly on the fun elements of the game. Providing the right content is an even more important issue in the  
705 case of NTDs such as ACL and VL, where complex and extensive information must be conveyed to the player. A related issue is how to balance this large volume of information with the necessary fun elements to provide a successful gameplay. This can perhaps be achieved, as suggested above, by creating different, but integrated, versions of the game for different categories of players  
710 (e.g. local citizens, healthcare professionals), as well as different levels of competence (beginner vs. advanced). Alternatively different types of players could be accommodated by providing them with different roles in collaborative game environment, as is done in multi-player online role-playing games.

There are, fortunately, a range of design and development methodologies,  
715 such as user-centred design and participatory design, which can be adopted to deal with this level of complexity in involving multidisciplinary groups of experts in the design, development and evaluation process. We have found tools such as oral and form-based debriefing (see Section 2) particularly useful in getting the opinions of our subject experts and potential users.

720 Another important issue, for which we have limited experience at this stage, is that of deployment. However, our experience with the One Health framework has demonstrated the challenges faced in deploying any community-based intervention mechanisms targeting diseases such as Leishmaniases, particularly in remote regions. We have found that, once again, the involvement of local  
725 community healthcare professionals is likely to be crucial to any successful deployment of serious games targeting NTDs.

Also as regards deployment of serious games in remote regions, one of the

main concerns developers tend to have, namely the unavailability of technology (e.g. mobile devices) and internet connectivity in these areas, does not seem to  
730 apply to the region in which we have conducted our research. The implication, in this instance, is that pre-conceived notions of remoteness should not *a priori* rule out exploration of a particular technological solution.

## 11. Conclusions

This paper addressed the potential benefits of using a serious game as part  
735 of community-based healthcare practices, to educate local citizens and health professionals about ways of controlling and reducing the spread of neglected tropical diseases in remote regions. We described the design process of a serious game architecture by a multidisciplinary team of computer scientists and medical researchers, and the use of a first instantiation of this system (Dr Ludens'  
740 LSG) as part of a strategy to raise awareness to the spread of Leishmaniasis in the tri-national region of South-Western Amazonia.

We have also described an evaluation of Dr Ludens' LSG by a multidisciplinary group of experts, who have suggested a number of improvements which could be made to make its future deployment more effective and widespread.  
745 We plan to make these suggested improvements before releasing Dr Ludens' LSG to the local population, and conducting a longitudinal study of its use and potential educational benefits.

## 12. Acknowledgements

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